AN INVESTIGATION OF FACTORS AFFECTING DOMESTIC TECHNOLOGY TRANSFER AT THE WRIGHT AERONAUTICAL LABORATORIES

THESIS

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Abstract

Transferring technology from federal R&D laboratories to the private sector is important in balancing national objectives in military security, economic vitality, and scientific and technological advances. This thesis investigates the factors affecting technology transfer from the Air Force's Wright Aeronautical Laboratories (AFWAL) to the private sector and recommends ways to enhance AFWAL's domestic technology transfer process. The study has three research objectives: 1) determine potential facilitators and barriers to technology transfer 2) investigate the facilitators and barriers to domestic technology transfer at AFWAL and 3) recommend techniques or methods AFWAL managers and scientists/engineers can use to enhance the domestic technology transfer process. Since data for this study is obtained from only one federal R&D center, findings are limited to this environment. However, the research findings suggest conceptual areas worthy of follow-on research for improving technology transfer.

The research uses Glaser and Strauss's grounded theory methodology as a guide for gathering and analyzing data. Data is collected by interviewing 18 AFWAL managers and scientists/engineers. The interview data is analyzed and placed into five conceptual categories. The five

conceptual categories are organizational behavior, individual behavior, technology distribution, technology documentation, and technology characteristics. The analysis shows that four factors affecting the technology transfer process exist in more than one category. These factors are AFWAL and private sector awareness and assessment of technology transfer capabilities, the lack of organizational and individual technology transfer guidance at AFWAL, the importance of technology transfer networks, and the use of technical reports for distributing technology.

Comparing the collected data to theoretical factors and attributes shows three areas for potential improvement in AFWAL's domestic technology transfer. The three areas are guidance for organizational and individual behavior, timeliness in technology documentation and distribution, and AFWAL and private sector awareness of each other's technology needs and capability.

The study also recommends that future research in this area must recognize organizational and individual behavior as important factors because they can either facilitate or hinder technology transfer from federal laboratories to the private sector.

AN INVESTIGATION OF FACTORS AFFECTING DOMESTIC TECHNOLOGY TRANSFER AT THE WRIGHT AERONAUTICAL LABORATORIES

I. Introduction

General Lew Allen, Jr., former United States Air Force Chief of Staff, chaired a National Science Foundation panel charged with developing strategies to regulate international technology transfer while maintaining a desirable balance between national objectives in military security, economic vitality, and scientific and technological advances (2:1). In 1987, the panel published three general principles for national policy to implement these strategies:

1) to promote the economic vitality of Free World countries,

2) to maintain and invigorate the domestic technological base, and

3) to cooperate with its allies to impede the Soviet Union and other Warsaw Pact countries in their efforts to acquire Western technology that can be used directly to enhance their military capability [2:4].

This thesis focuses on the panel's second principle for national policy; maintaining and invigorating the domestic technological base. Specifically, the focus of this thesis will center on the use of federally funded research

and development (R&D) technology and capability to maintain and invigorate the domestic technological base by enhancing the private sector's access to national research and development resources.

Federal technology transfer is a process for transferring technology from federally funded R&D facilities to the private sector (26:13). A general consensus among researchers is that an effective domestic technology transfer program benefits society in many ways (2; 27; 39).

> Societal problems such as lagging productivity, inferior product quality, a negative balance of trade, and loss of traditional markets to foreign competitors could all diminish in importance with more successful diffusion of technologies to private industry [39:43].

Federal technology transfer is a process which enables federal R&D technology and capability to maintain and invigorate the domestic technological base. An invigorated and sustained domestic technological base insures economic vitality and protects national security (2:15).

For the purpose of this study, federal technology transfer from federal R&D facilities to the private sector will be referred to as domestic technology transfer. According to John S. Gilmore, technology transfer is the "purposive continuous effort to move technical devices, material, methods, and/or information from the point of

discovery or development to new users" (22:82). A more common meaning of technology transfer is "the adaptation of existing knowledge or technology to serve a new purpose, or its adoption and use by a new group of people" (25:56). The transfer of technology discovered and developed by federal R&D organizations to the private sector, a new user group, is referred to as domestic technology transfer for this study.

The domestic technology transfer process is generally categorized as either an active or passive process (39:44). Active domestic technology transfer occurs when the private sector's "needs and wants are identified and efforts are made to satisfy these through technologically-innovative products and processes" (6:4). Passive domestic technology transfer is less interactive. It insures "research findings are disseminated in the expectations that new product and process development will ensue" (6:4). These two categories often are associated with "technology push," an active process and "market pull," the passive process (39:44).

The AFWAL Environment

The Air Force Wright Aeronautical Laboratories (AFWAL) at Wright-Patterson AFB, Ohio form a federal R&D organization. In 1975, four separate and distinct laboratories, Air Force Aero Propulsion Laboratory, Air

Force Avionics Laboratory, Air Force Flight Dynamics Laboratory, and Air Force Materials Laboratory, formed AFWAL (1). In 1980 the four laboratories were consolidated into one unit, directed by the AFWAL Commander and his staff (1). Two years later AFWAL became a part of the Air Force's Aeronautical Systems Division (ASD) and reported directly to the ASD Commander (1). Today AFWAL remains a part of ASD and still retains the original four functional laboratories. However, AFWAL has been directed to reorganize itself as the Wright Research and Development Center (WRDC) on October 1, 1988 (32).

The WRDC will retain the four existing laboratories and add a fifth, the Electronics Technology Laboratory (32). It will also have four directorates, Cockpit Integration, Manufacturing Technology, Signature Technology, and Technology Exploitation. The first three directorates mentioned will "provide more focused activities which are of extremely high interest to the Air Force and are multidisciplined in nature" (32). The Technology Exploitation Directorate will have a similar but expanded role.

> The Technology Exploitation Directorate will be an especially important organization which plans and coordinates selected WRDC activities that cut across multiple technology disciplines, performs quantitative assessments to determine payoffs for competing technologies, fosters new initiatives, and provides coordination and oversight of our significant advanced development and technology transition activities [32].

AFWAL technology transfer activities prior to this reorganization initiative indicate it has an active approach towards domestic technology transfer (20). In 1984, a Memorandum of Agreement between Ohio Governor Richard Celeste and the Commander of Aeronautical Systems Division linked AFWAL with the Ohio Technology Transfer Organization (OTTO) to mutually work towards enhancing domestic technology transfer within the state (7:55). According to the Memorandum of Agreement, the OTTO agents would contact AFWAL with requests for technology and technical assistance. During 1984, AFWAL and OTTO worked together in 51 domestic technology transfer projects (7:55). To date, the AFWAL/OTTO agreement continues to be an effective mechanism for linking the private sector with AFWAL R&D resources (20). Additionallly, AFWAL accomplishes domestic technology transfer by working with the the Federal Laboratory Consortium (FLC) for Technology Transfer. The FLC is an organization linking representatives of over 600 federal laboratories who assist and advise in technology transfer projects (11). AFWAL's manager for the Office of Research and Technology Application is also one of six FLC regional coordinators (11:3). Recent legislation, such as the Stevenson-Wydler Technology Innovation Act of 1980 and The Federal Technology Transfer Act of 1986, allows AFWAL as well as all other federal R&D organizations to become even more involved in the domestic technology transfer process.

Federal Technology Transfer Legislation and Executive Policy

The U.S. Congress has acted to promote domestic technology transfer prior to the legislation passed during the 1980's. The Cooperative Extension Service was established by the Smith-Lever Act of 1914 to transfer the results of agricultural research to the American farmer (9:176). In 1958 the National Aeronautics and Space Administration (NASA) was created by the the National Aeronautics and Space Act. The act implies the NASA Administrator shall "provide for the widest possible practicable and appropriate dissemination of information concerning its [NASA] activities and the results thereof" (9:71). Additionally, the act provided NASA with the objective to establish long-range studies of space activities which could benefit peaceful and scientific purposes (9:71).

More recently, the National Science and Technology Policy, Organization, and Priorities Act of 1976 strengthened government emphasis on technology transfer (26:27). The act established an Office of Science and Technology Policy within the executive branch and the President's Committee on Science and Technology. This Presidental advisory committee was created "for the purpose of assuring state, regional and local input to science, engineering, and technology decisions" (26:27).

During the 1980's, congressional acts concerning technology transfer were intended to go beyond providing local input to policy by increasing private sector use of federally funded R&D laboratories such as AFWAL. This intent is evident in the Stevenson-Wydler Technology Innovation Act of 1980 and amending legislation, The Federal Technology Transfer Act of 1986. The Stevenson-Wydler Technology Innovation Act "makes the transfer of Federal technology to industry, States, and localities a national policy and the duty of each laboratory" (37:3). The Federal Technology Transfer Act added to the Stevenson-Wydler Technology Innovation Act. Its purpose is "to improve the transfer of commercially useful technologies from the Federal laboratories and into the private sector" (37:1).

Both congressional acts provide for increased private sector use of federally funded R&D which is budgeted for $131.5 billion in 1988 (4:29). Of the total budgeted amount, the 600 federal laboratories account for $16.4 billion (4:29). The Stevenson-Wydler Technology Innovation Act of 1980 and The Federal Technology Act of 1986 increase the private sector's ability to benefit from this government investment in R&D. Each legislative acts' impact on the domestic technology transfer process are presented individually in the next two sections.

Stevenson-Wydler Technology Innovation Act of 1980.

As mentioned earlier, provisions in the Stevenson-Wydler Technology Innovation Act make the transfer of Federal technology to industry, States, and localities a national policy and the duty of each laboratory. Section 11(a) of the act outlines the national policy for technology transfer.

> It is the continuing responsibility of the Federal Government to ensure the full use of the results of the Nation's Federal investment in research and development. To this end the Federal Government shall strive where appropriate to transfer federally owned or originated technology to State and local government and to the private sector [38].

In addition to establishing a national policy for technology transfer, the act also provided a framework for the utilization of federally developed technology. Section 11(b) established this framework by directing each federal laboratory to establish an Office of Research and Technology Applications with the following functions:

(1) to prepare an application assessment of each research and development project in which that laboratory is engaged which has potential for successful application in State or local government or in private industry.

(2) to provide and disseminate information on federally owned or originated products, processes, and services having potential application to State and local governments and to private industry.

(3) to cooperate with and assist the Center for the Utilization of Federal Technology and other organizations which link the research and

development resources of that laboratory and the Federal Government as a whole to potential users in state and local government and private industry, and

(4) to provide technical assistance in response to requests from State and local government officials [38].

The act also established the Center for the Utilization of Federal Technology within the Department of Commerce to "serve as a central clearinghouse for the collection, dissemination, and transfer of information on federally owned or originated technologies having potential application ..." as well as other administrative duties (38).

The Federal Technology Transfer Act of 1986. This act primarily amended the Stevenson-Wydler Technology Innovation Act of 1980. The Federal Technology Transfer Act of 1986 increased federal laboratories' ability to help the public and private sector by allowing them to enter into cooperative agreements with the public and private sector. Section 12(a) grants each Federal agency the general authority to permit laboratory directors to:

1) enter into cooperative research and development agreements with private and other government entities on behalf of such agency: and

2) to negotiate licensing agreements [8:19].

The act also provided the formal charter and funding through 1991 for the Federal Laboratory Consortium for Technology Transfer, an organization linking laboratory representatives who assist and advise technology transfer

(8:19). The Federal Laboratory Consortium had operated without formal government charter since 1971 (31:26). Final provisons allow laboratory employees to financially benefit from inventions, royalties, or licensing agreements generated by themselves while working for the laboratory (8:20).

Executive Order 12591 . On April 10, 1987, President Reagan released Executive Order 12591, "Facilitating Access to Science and Technology," to ensure:

> Federal agencies and laboratories assist universities and the private sector in broadening our technology base by moving new knowledge from the research laboratory into the development of new products and processes [29:1].

Executive Order 12591 contains several directives to the Federal departments and agencies. One of those directives instructs the Federal departments and agencies to improve domestic technology transfer by:

1) encouraging Federal laboratories to collaborate with business, particularly small business, through cooperative research and development agreements,

2) licensing intellectual property the Federal laboratories participate in developing,

3) encouraging "science entrepreneurs" to act as conduits between Federal laboratories and the private sector,

4) implementing royalty-sharing programs, and

5) developing uniform policy allowing Federal contractors to retain proprietary rights to federally generated technology in exchange for free use by the government [30:1].

Other directives in Executive Order 12591 include establishing a "Technology Share Program," a scientist/engineer exchange between the private sector and the Federal laboratories, and identifying as well as accelerating the transfer of Department of Defense (DOD) technologies useful to industry and universities (30:1-2). Additionally, the Executive Order instructed a review within one year to assess the Federal laboratories' technology transfer progress as well as other instructions (30:2).

Problem Statement/Research Objectives

In accordance with legislative and congressional intent, AFWAL, as well as all other federally-funded laboratories, has the responsibility to enhance the transfer of federally developed technology to the private sector. Senior AFWAL managers are seeking methods and techniques to improve current domestic technology transfer efforts to the private sector (19). As previously mentioned, improving the domestic technology transfer process allows increased return on the nation's federal R&D investment. Thus, the research problem for this thesis is to determine ways AFWAL can enhance technology transfer to the private sector.

This thesis examines the factors and attributes affecting the technology transfer process to find ways to enhance AFWAL's domestic technology transfer. The

literature generally recognizes successful techniques and methods for transferring technology as facilitators to the technology transfer process. For example, federally organized technology conferences are one of the leading facilitators for technology transfer (31:3). Other factors, such as similiar federal and private sector technology needs, facilitate technology transfer (7; 27). Conversely, those factors and attributes which inhibit technology transfer are a barrier to the process. Federal laboratory awareness of the private sector's technology needs is a transfer barrier (7; 14; 16; 39).

Thus, the research objectives of this study are; (1) to identify potential facilitators and barriers to technology transfer, (2) determine and investigate the facilitators and barriers that exist at AFWAL, and (3) recommend ways to improve AFWAL's domestic technology transfer by enhancing the facilitators and minimizing or eliminating the barriers.

Research Questions

The following research questions will guide the research:

1) What are potential facilitators and barriers to technology transfer?

2) What facilitators and barriers to domestic technology transfer exist at AFWAL?

3) What techniques, methods, or factors can AFWAL managers and scientists/engineers use to enhance the domestic technology transfer process?

Scope of Study

The research will be limited to the study of domestic technology transfer within the AFWAL enivronment. The research findings will also suggest ways to enhance those facilitators and minimize or eliminate the barriers. Since the site for this research is AFWAL, the findings can not be generalized to all federal R&D organizations. However, the research findings should suggest techniques or methods worthy of follow-on research for improving technology transfer at other federal organizations.

Summary

This chapter began by relating domestic technology transfer's importance in balancing the national objectives in military security, economic vitality, and scientific and technological advances (2). Next, for the purpose of this study, domestic technology transfer was defined as the adaption or adoption of federal knowledge or technology by the private sector. The domestic technology transfer process is either active by identifying and satisfying private sector needs or passive by disseminating federal research findings for the private sector's use.

The Air Force's Wright Aeronautical Laboratories (AFWAL) has an active approach to the domestic technology transfer process. Recent legislation, such as the Stevenson-Wydler Technolgy Innovation Act of 1980 and The

Federal Technology Transfer Act of 1986, allow AFWAL to become even more involved in the domestic technology transfer process than was previously possible. The major purpose of this research is to examine AFWAL's current domestic technology transfer process and suggest ways to improve it.

II. Literature Review

The literature review is organized into two sections. The first section presents technology transfer theory found in the literature. The second section identifies facilitators and barriers to the technology transfer process. These two sections establish a frame of reference for understanding and analyzing AFWAL's domestic technology transfer process.

Technology Transfer Theory

Reviewing the literature about technology transfer reveals many theories which describe the technology transfer process and the mechanisms which affect the transfer of technology. Most theories have been reduced to models which describe the transfer process. Four theoretical models are presented to establish a basis for understanding the technology transfer process. The models chosen are a predictive model, an innovation model, a marketing model, and a model for government agencies and laboratories.

The researcher uses these four models because they generally explain and describe theoretical foundations for the technology transfer process. The predictive model presents what factors can determine the successful transfer of technology from the technology source to the

technology user. The innovation model indicates why and when technology transfer is needed during the innovation process. The marketing model describes how a technology source can promote the transfer of technology. Finally, the model for government agencies and laboratories describes formal mechanisms for handling the transfer of technology. Awareness of these four models is useful in understanding the theoretical foundations for technology transfer.

Predictive Model for Technology Transfer. In Chapter 1, technology transfer was defined as technology's movement from a source or originator to a technology user. In this study the federal laboratories are the technology source and the private sector is considered the potential technology user. Much technology transfer research references the technology transfer process model of Drs. James A. Jolly and J. W. Creighton. Jolly and Creighton simplify the technology transfer process as a transfer mechanism linking the technology source or supplier with the technology user or receiver. The transfer mechanism between the source and user represents the interaction of people (23:2). Figure 1 shows this basic relationship.

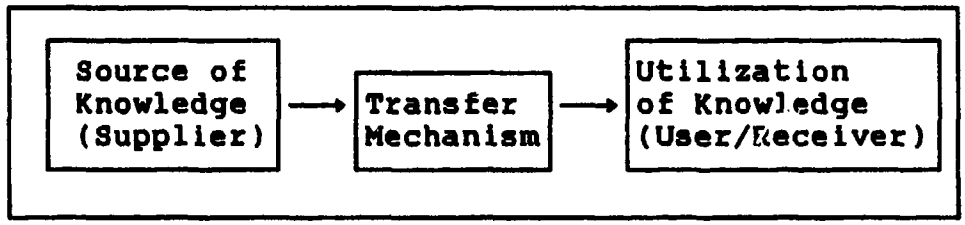

Figure 1. A Simplified View of the Transfer Mechanism (23:2)

According to Jolly and Creighton the transfer mechanism between the source and user represents the interaction of people and that interaction is affected by formal and informal factors (23:2-3). They state that "the formal factors are procedural and the informal factors are behavioral" (23:3). The formal factors affecting the transfer process are: method of information documentation, information distribution system, user's formal organization, and the user's contribution to selecting transfer projects (23:4). Informal factors in the transfer process are; the user's capacity, individuals who act as informal linkers in the receiving organization, information credibility, perceived reward to the receiver, and the receivers willingness to accept change (23:4-11). Figure 2 graphically depicts Jolly and Creighton's technology transfer model.

Expanding and applying the transfer mechanism's formal and informal factors between federal laboratories and the private sector lends greater insight to the usefulness of

Jolly and Creighton's model. The factors and associated descriptions are presented in Table 1.

The informal linker factor has received considerable emphasis in the literature and bears further explanation. A linker is an individual who "mediates between his organizational colleagues and the world outside, and he effectively couples the organization to scientific and technological activity in the world at large" (23:10). Linkers primarily gather technological information from "informal, interpersonal channels of communication" (23:10). Additionally, the linker acts as the "gatekeeper" who controls and filters inputs to his organization (23:10). Additional research shows that the linker factor expands beyond the technology user's organization to include any individual who links technology sources to technology users (33:24). These attributes indicate the pivotal role the linker has in establishing and maintaining an organization's contact with technology sources.

Jolly and Creighton's technology transfer model provides a basic approach to understanding the movement of technology from source to reciever/user and can be applied to technology's movement from federal laboratories and the private sector. However, there are other approaches which lend insight to understanding the technology transfer

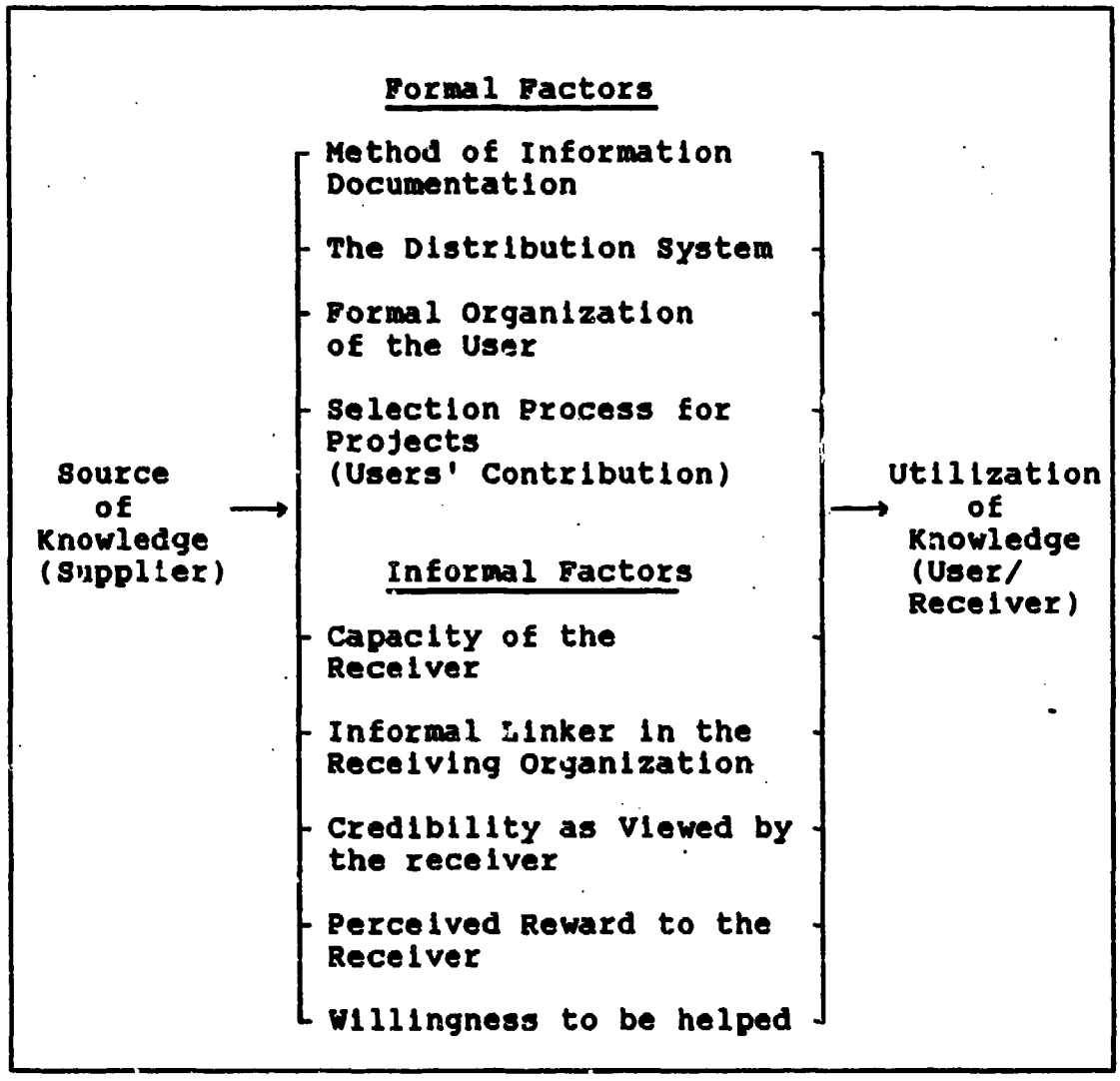

Figure 2. An Expansion of the Predictive Technology Transfer Model (23:4)

Table 1. Federal Laboratory/Private Sector Interaction Applied to Jolly and Creighton's Predictive Model

Factor	Description
Documentation	Format, specification, and presentation of technology or information for the private sector
Distribution	Private sector access to the physical channels through which technology moves as well as formal laboratory distribution plans
Formal User Organization	Organizational structure and tendencies conducive to change and innovation
Selection Process for Projects	Private sector input to the research and development projects by the federal laboratories
User Capacity	Private sector ability and capability utilize new and/or innovative technology
Informal Linker in the Receiving Organization	Individual or individuals who link or couple the private sector organization to the federal laboratories
Credibility as Viewed by the Receiver	Private sector assessment of the reliability of the technology developed by federal laboratories
Perceived Reward to the Receiver	Both intrinsic and extrinsic rewards for the private sector organization or individual to implement technology
Willingness to be helped	Private sector willingness and/or desire to accept change (23:5-12)

process. Another approach considers technology transfer's role during innovation.

Innovation Model for Technology Transfer. Technology must be transferred for a reason. A reason for transferring technology is its use in innovation by the private sector to create or improve products, processes, or services. According to Roberts and Frohman as reported by Captain Harvey D. Jones in his study, The Commercialization of New Technologies: Transfer from Laboratory to Firm, the innovation model has six stages. Those six stages are:

Stage 1: Recognition of opportunity

Stage 2: Idea formulation

Stage 3: Problem solving

Stage 4: Prototype solution

Stage 5: Commercial development

Stage 6: Technology utilization and diffusion (24:16)

The first stage's objective is to recognize and identify new product and process opportunities (24:16). During Stage 2, opportunities are matched with market requirements as well as economic return on investment to determine feasibility (24:16). The third stage, problem solving, consists of searching for the "technology and market environments and use of identified sources and resources to complement and supplement internal R&D

activities in order to solve the technical problems inherent in the innovation" (24:17).

The remaining stages are concerned with developing and testing a functional prototype, refining the prototype for commercialization, and eventual technology utilization and diffussion (24:18). As the innovative product, process or service progresses through these six stages the transfer of technology from federal laboratory to the private sector can be of great value. Jones reports how technolgy transfer may occur in the different stages:

> in stage 1, it can provide the firm with new ideas or technical opportunites for new products;
>
> in stage 3, it can provide the firm with problem solving information and techniques to move on-going innovation projects along;
>
> in stage 3, it can also provide the R&D environment with spinoff information about developments and discoveries made by the innovating organization;
>
> in stage 4, it can provide the firm with information needed to develop functional prototypes and achieve technical completion of the innovation;
>
> in stage 6, it can be used to diffuse technologies throughout the R&D environment for the reasons listed above [24:19-20].

Figure 3 shows the relationship between the technology source and the innovation process during these stages. Stages 1, 3, and 4 require technology transfer from the technology source or environment. Additionally, Stage 3 shows an interaction between the source and the reciever. In Stage 6, the technological knowledge gained from the

innovation is returned to technology sources as well as diffused through the market place (24:18).

The model presented by Jones shows that technology transfer is a necessary "link between the innovating organization and the R&D environment" (24:19). From the model it appears that the greatest technology transfer interaction occurs during the problem solving stage. Captain Jones' study concludes that innovation's success or failure is dependent on continual assistance and cooperation with the technology source. The model, however, does not indicate in what ways technology transfer occurs, just the stages in which it is an essential part of the innovation process. The next model discussed, a marketing model, lends insight into promoting technology transfer.

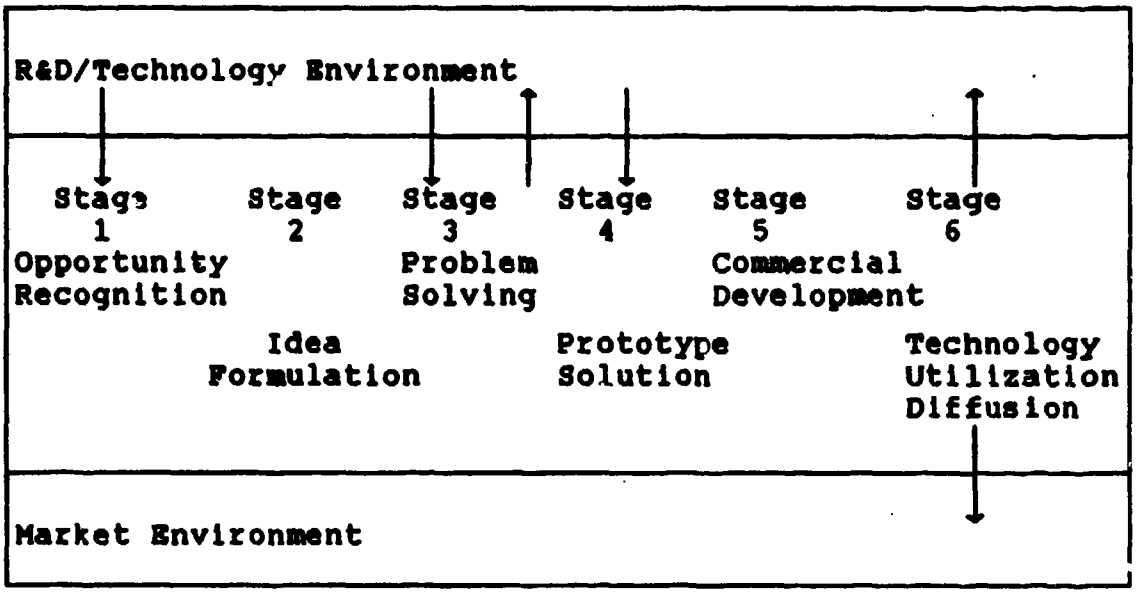

Figure 3. The Role of Technology Transfer in the in the Innovation Process (24:21)

A Marketing Model for Technology Transfer. Dr. Richard O. Weijo, a Market Research Scientist with Pacific Northwest Laboratory, suggests applying marketing theory to develop strategy for promoting technology transfer to the private sector (39:43). As mentioned earlier in Chapter 1, technology transfer strategies generally are either passive or active. Passive technology transfer results from the private sector's need to seek technical information in problem solving (39:44). Active technology transfer results from an innovative laboratory- developed technology which the private sector can apply in creating a new product, process, or service (39:44). Dr. Weijo describes two different types of active technology transfer.

Dr. Weijo divides active technology transfer according to the audience which can apply an innovative technology. The first audience is private sector scientists and engineers capable of applying a technology to diverse industries (39:45). Dr. Weijo terms this role-directed technology transfer because of the role scientist and engineers have in identifying "the products and processes that can be developed from a new technological innovation" (39:45). The other type of active technology transfer is organization-directed. According to Dr. Weijo, organization-directed technology transfer targets innovative and adoptive organizations

within specific industries (39:45). He makes the following statement about organization-directed technology transfer.

> The organization-directed strategy can be described as the most active transfer strategy because it remains the responsibility of personnel at the government agencies to actively seek out the industries and the firms most likely to adopt a new technology. The engineers, scientists, and market researchers employed in national laboratories and other government agencies must make the conceptual leap to identify the products and processes that can be developed from a new technological innovation [39:45].

The type of technology transfer strategy used, whether it is passive, role-directed, or organization-directed, will affect the mechanisms used to transfer technology. Passive technology transfer attempts to "make information accessible to those individuals and organizations searching for solutions to identified customer problems/needs" (39:51). This can be accomplished through a publication database such as the National Technical Information Services (NTIS), professional journals, trade publications, and conference presentations (39:51). Role-directed technology transfer's objective is to inform scientists and engineers within an organization of government laboratory technology. This is accomplished through publications, trade association and professional conferences, technology fairs, and industry teams. An industry team is a NASA developed approach to identify products or processes for

the private sector. Organization-directed technology transfer is accomplished in more personal ways. Personal contact, R&D personnel transfer, onsite visits, and demonstration projects are a few of the means to transfer technology according to an orgainzation-directed strategy (39:46-54). Table 2 summarizes the purpose and technology transfer mechanisms for passive, role-directed, and organization-directed strategies. An absolute distinction between the three different approaches to technology transfer is difficult to identify. For that reason, it can be said that the three are interrelated (39:58). To show how they are interrelated, Dr. Weijo places them on a technology transfer continuum according to the audience the technology is intended for. Figure 4 shows the relative position on the continuum.

The following quotation from Dr. Weijo's work summarizes the relationship between the different stategies.

> The technology transfer continuum indicates that there are really more than just three technology transfer strategies. Each technology transfer strategy described in this paper actually portrays a portion of the range of possible programs. The primary task of all technology transfer programming is to narrow the target audience as much as possible to most effectively use the resources available to a government agency [39:58].

Dr. Weijo's theory for promoting technology by identifying the most appropriate way to transfer technology contributes to the theoretical foundation for technology transfer.

Additionally, Jones' technology transfer study relative to the innovation process shows why and when technology transfer needs to occur. Jolly and Creighton's predictive model needs to occur. Jolly and Creighton's predictive model describes the factors which affect the successful

Table 2. Strategies for Promoting Technology Transfer to the Private Sector (39:46)

Technology Transfer Strategy	Purpose	Transfer Mechanisms
Passive	To make information accessible to those individuals and organizations searching for solutions to customer/ society problems	Technical databases NTIS Professional journals Trade publications Conferences Workshops
Role-directed	To actively promote awareness of new technology to individuals occupying boundary-spanning roles in organizations	Professional journals and seminar presentations targeted to certain disciplines Trade publications and seminar presentations targeted to industry groups or national associations Technology fairs Industry teams
Organization directed	To actively promote the adoption of new product or process concepts to innovator firms in an industry	Transfer of R&D personnel Demonstration projects Personal Contacts Onsite visits Joint Ventures Tax incentives

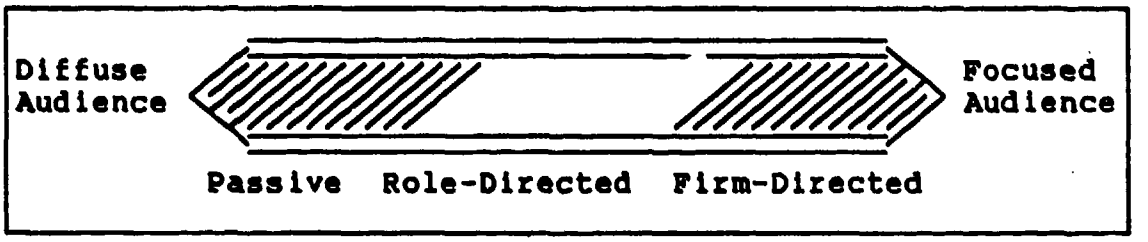

Figure 4. The Technology Transfer Continuum (39:58)

transfer of technology. One last model, a technology transfer model for government agencies and laboratories, presents how a federal laboratory can react to the private sector's need for technology transfer.

Government Agency/Laboratory Model for Technology Transfer. The Department of Commerce, Office of Patent Policy and Technology Transfer, and the Economic Development Adminstration sponsored a study to examine organizational mechanisms for technology transfer from the federal laboratories to small and medium size business and non- federal government agencies (27:1). The study, completed by the University of Illinois' Center for Urban Economic Development, made two major recommendations. First, the study recommended establishing a national Industrial Extension System (IES) similar to the Department of Agriculture's Cooperative Extension Service. The IES would assist industry, primarily smaller firms who lack substantial R&D resources, through a state-wide agent network (27:28). Secondly, the study recommended

"adaptations to the existing mechanism for accessing information and technologies within the federal laboratories" (27:1). Each of these recommendations add to the theoretical foundations of technology transfer.

The concept of an IES is to provide a link between industry and federal laboratories. Through technology centers and its agents, an IES would help industry "in accessing federal laboratory technology and technical information and commercializing or implementing this technology" (27:1). Throughout the Department of Commerce's study, the service provided by an IES is referred to as a third party brokering system. A third party brokering system assists the technology user "in defining the problem in technological terms, and may also be involved in the steps necessary to implement its recommendations" (27:14). Trade and professional associations have traditionally acted as third party brokers to their members (27:11). However, portions of an industry or an entire industry may not have access to such an association (27:13). An IES would provide smaller business with a third party brokering system to the federal laboratories's technology resources.

The study's second recommendation also proposed improving the link between federal labortories and the private sector by enhancing the current mechanisms which allow the private sector to benefit from federal

laboratory technology resources. This improvement could be achieved using database searches, federal technology assesments, and criteria for deterimining the extent of private sector use of federal laboratory resources.

> We recommend the establishment of a federal laboratory data base to include this information and an ordered search process that could make more efficient use of laboratory personnel and expertise. Additional suggested adaptations to federal technolgoy transfer efforts include a consistent method for commercial evaluation of technologies and standard criteria for private sector use of federal laboratory expertise [27:3].

The primary resources which could benefit the private sector are the federal laboratories' technology and technical information which have potential secondary uses in the private sector (27:5).

According to the study, secondary use of federal technology is accomplished in two ways, proactively and reactively (27:5). The proactive and reactive transfer of technology is similar to Dr. Weijo's definition of active and passive technology transfer. A proactive transfer mechanism identifies federally developed technologies to be promoted toward specific users (27:5) A reactive transfer mechanism responds to potential user requests with federal technology and information (27:5).

In both instances, proactive or reactive transfer, the federal laboratory's Office of Research and Technology Assessment (ORTA) has a central role. Proactive transfer requires the ORTA to identify secondary users for all or

portions of a distinct federal technology which can be patented and liscensed to the secondary user (27:5). Figure 5 depicts how a distinct technology would be assessed by the ORTA, classified by the agency patent office and distributed and/or marketed to potential users.

Reactive transfer, which is triggered by a potential technology user's request, is directed "through the ORTA, through other laboratory personnel, or through outside sources of assistance" (27:7). Other sources of assistance are provided by the Federal Laboratory Consortium (FLC), third party brokers, and private or

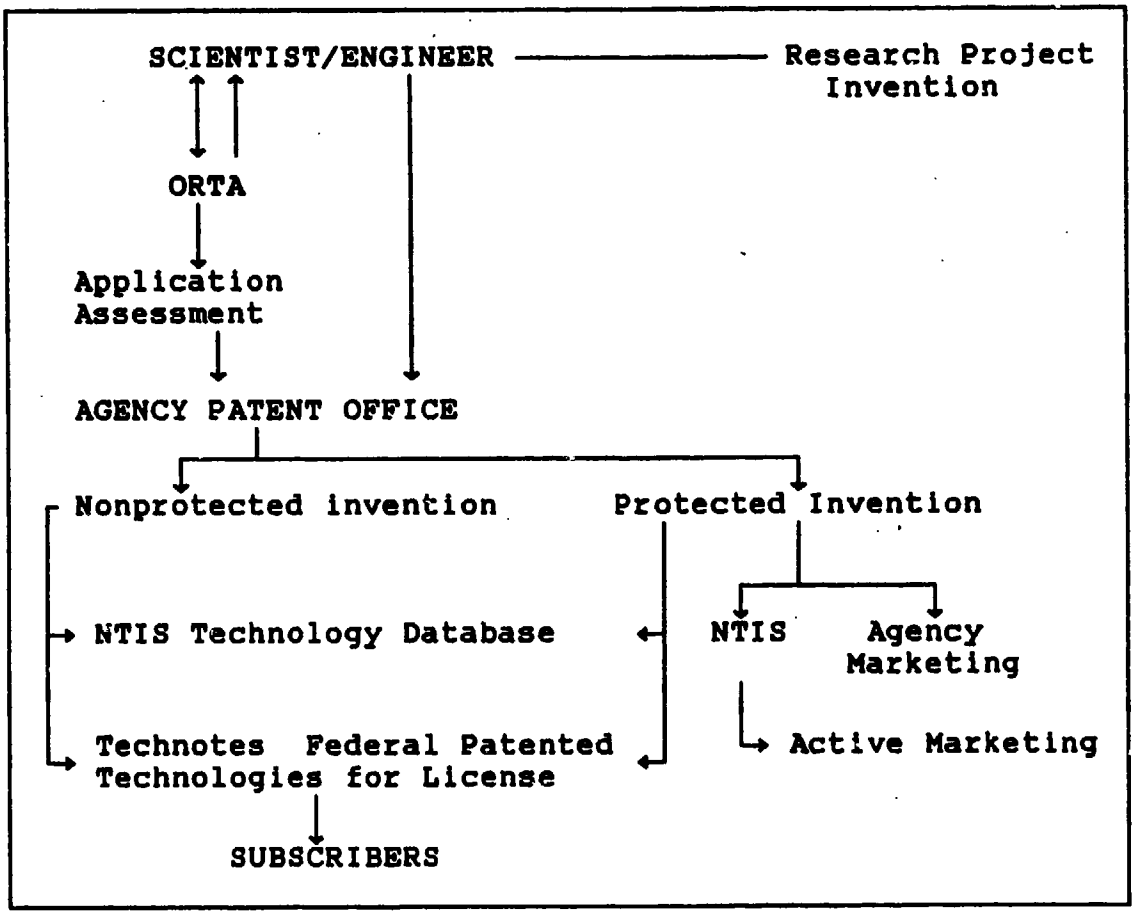

Figure 5. Proactive Technology Transfer Mechanism (27:Figure 4.1)

public database searches (27:7). Figure 6 shows the relationship of these other sources and the ORTA in response to a potential technology user's request.

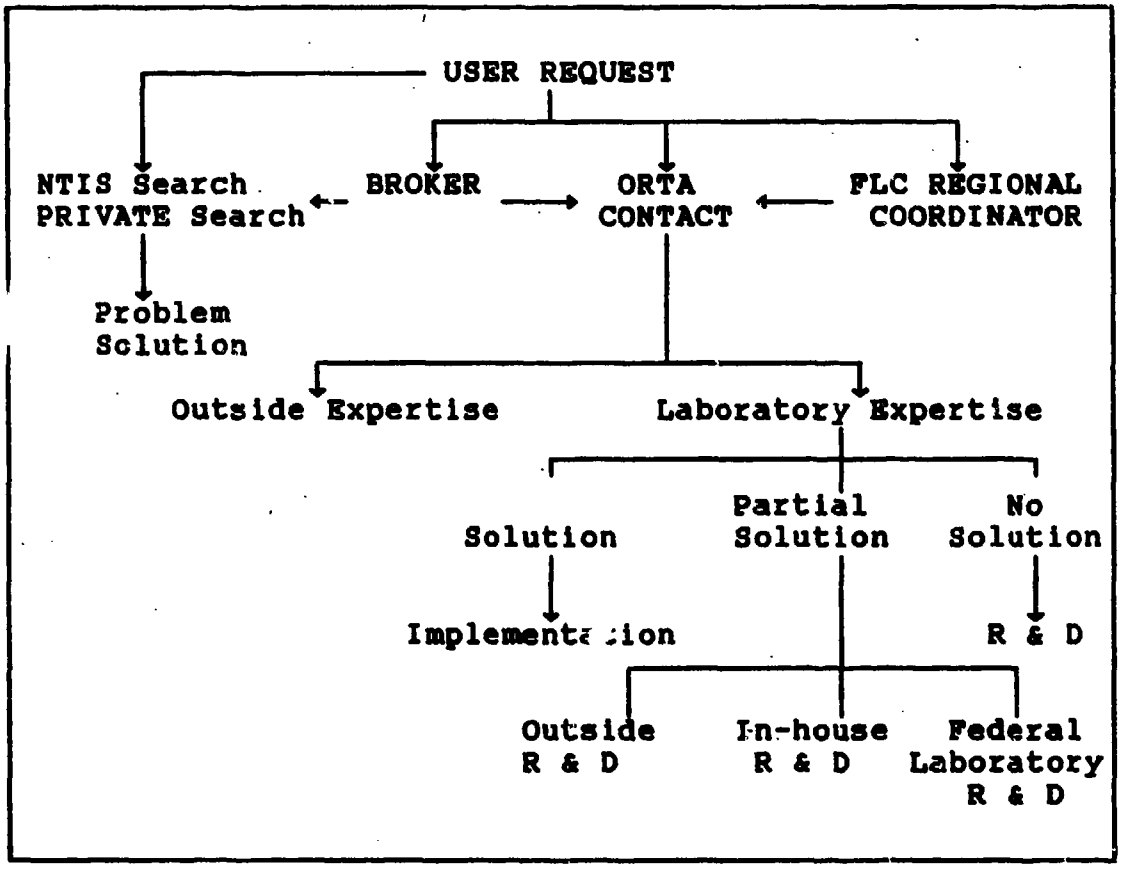

Figure 6. Reactive Technology Transfer Mechansim (27:Figure 4.2)

Federal laboratories can develop a technology transfer program using either a proactive or reactive transfer mechanism and/or a combination of both. In developing a technology transfer program, the ORTA or another entity "must exist with the primary focus of providing a translation function between the sources of

technology/technical information and the client groups" (27:25). According to the proactive and reactive models proposed, the ORTA appears to be the primary provider for the translation function. If an IES is established, it too would provide a necessary translation function. No matter what entity provides the translation function between the federal laboratories and private sector users, federal laboratories could use the proactive and reactive mechanisms or a combination of both.

This concludes the presentation of the four models choosen to establish a basis for understanding the technology transfer process. Jolly and Creighton's predictive model presented formal and informal factors which affect technology transfer. The innovative model showed why and when technology transfer occurs during the innovation process. Next, strategies for promoting passive, role-directed, and organization-directed technology were discussed in a marketing model. Finally, a model for government agencies and laboratories described formal mechanisms for handling the transfer of technology. Identifying and discussing facilitators and barriers to the technology transfer process will enchance the theoretical foundations which have already been presented.

Technology Transfer Facilitators and Barriers

The previous section presented some factors and attributes which, by themselves or combined, affect the

technology transfer process. Factors and attributes affecting technology transfer can facilitate or hinder the transfer process. This section's purpose is to organize, present, and describe factors and attributes that facilitate or hinder technology transfer from the federal laboratories to the private sector.

In Chapter 1, successful techniques or methods that facilitate technology transfer, such as government sponsored technology conferences, are identified as facilitators to the transfer process. Other factors like similar technology needs for the federal laboratory and the private sector create a natural cause for technology transfer (7; 27). Barriers also exist which hinder or prevent the federal laboratory from transferring technology to the private sector.

In the following discussion the factors and attributes that facilitate or hinder the domestic technology transfer process are presented according to the formal and informal categories used in Jolly and Creighton's predictive model. Table 3 restates the predictive model's factors and lists the descriptions and properties for those factors.

Documentation. The documentation of federal laboratory technology affects the transfer of technology. Typically, the federal laboratories document their R&D findings with technical reports or summaries (5; 21).

Table 3. Formal and Informal Factor Categories, Descriptions, and Properties From Jolly and Creighton's Predictive Model for Technology Transfer

CATEGORY	DESCRIPTION	PROPERTIES
Documentation	Format, specification, and presentation of technology or information	Understandable Meaningful Communicative
Distribution	Private sector access to physical channels used to transfer technology	Easy Access Plans
Formal User Organization	Organizational structure/ tendencies conducive to change and innovation	Resources Attitudes Management
Selection of Projects	Input to federal laboratory R&D projects by private sector	Collaboration Control
User Capacity	Private sector capability to utilize new and/or innovative technology	Education Experience Wealth
Informal Linker in Receiving Organization	Personnel who link or couple private sector organizations to the federal laboratories	From User From Source In Between
Credibility as Viewed by the Receiver	Private sector reliability assesment of federal laboratory technology.	Believable Credible Reliable
Receiver Reward Perception	Intrinsic/extrinsic rewards for the private sector to implement federal technology	Positive Negative
Willingness to be helped	Private sector willingness or desire to accept change	Resistance Motivation (23; 33)

Handbooks and manuals describing production processes or product development are also used to document the federal laboratories R&D (5). Additionally, videotapes of experimental procedures and results document R&D efforts (21). These documentation efforts, while facilitating the transfer of technology, have barriers associated with them. Any documentation must use effective communication skills. Dr. Weijo reports the clarity of technical reports as a barrier to effective technology transfer (39). Also, Dr. Weijo as well as the Department of Commerce study, Facilitating Federal Technology Transfer to Small and Medium Sized Business and State and Local Governments, identify the time delay between technology development and formal documentation as a barrier to the transfer process (27; 39).

Distribution. The technique or method used to transfer technology receives the most attention in the literature. One of the primary facilitators to technology transfer is personal contact (14; 15; 18; 21; 27; 31; 35; 39). Particia B. Herdendorf, a former Administrator for the Ohio Technology Transfer Organization, supports personal contact as the best way to facilitate technology transfer. She reports personal discussions and natural visits between the technology supplier and user work best to transfer technology (18:2). The proceedings from an AIAA/NASA conference on aerospace technology transfer to

the public sector summarizes the significance of personal contact as the most effective factor in transferring technology.

> By far, the most successful mechanism for transferring advanced technology to private-sector users is by extensive and intensive person-to-person communications. The technology transfer process is generally successufully achieved only when both the technology developer and the prospective user have accumulated sufficient knowledge of each other's operation [15:82].

Personal contact between technology supplier and technology user occurs in several ways. Transferring personnel between public and private sector R&D organizations and consulting agreements facilitate technology transfer (21; 27; 35). A Government Accounting Office study of 10 federal laboratories found that visits to federal laboratories by small businesses not only helped to establish personal contacts but also familiarized technology users with federal laboratory capability and resources (14:7). Personal contacts established in professional and trade associations are also an important facilitator in the technology transfer process (16; 21; 27; 35). The Department of Commerce study reports professional and trade associations have traditionally played a central role in the transfer of technology from the public to the private sector because they bring together government researchers and private sector users (27:11). Government or private sector sponsored technology conferences also facilitate personal

contact by bringing together government researchers and the private sector (16; 31; 39).

Several barriers to personal contact exist. One is the geographic separation between federal laboratories and potential private sector users (27; 35). Another is the private sector's awareness of federal laboratory sponsored events such as technology conferences (14:10). A third barrier is the lack of federal laboratory manpower and funding for domestic technology transfer activities (39:69).

These barriers can be overcome with technical reports distributed through scientific and technical information centers. The Department of Commerce identifies the National Technical Information Service (NTIS) as the "central source of research reports and other analyses that are developed by the vast Federal network of departments, bureaus, and agencies" (7:46). The Department of Defense maintains a database in the Defense Logistics Agency's Defense Technical Information Center (DTIC) for scientific and technical reports. The database contains reports of completed and on- going government sponsored research and development (3:6). NASA and the Strategic Defense Initiative Office also have scientific and technical databases which the private sector can access. Literature sources like professional journals and

trade publications also publish federal R&D reports (39:56).

The distribution of federal technical reports also presents barriers to technology transfer. Distributing technology through technical reports delays the transfer of technology from the federal laboratories to the private sector. A 1984 Department of Energy study found "this delay can be as long as one and a half to two years" (39:51). Dr. Weijo cited a 1985 study by Olken who identified three other barriers to effective technology transfer by distributing technical reports. They are the laboratories failure to write up new technology developments and make them accessible and understandable as well as the chaotic storage of material describing technology developments (39:51). The security classification of militarily critical technology developed in federal laboratories, especially the Department of Defense and Department of Energy laboratories, is another barrier in distributing technical reports (16; 31; 39).

User's Formal Organization, Capacity, and Willingness To Be Helped. The studies by Paul Dawson and Dr. Weijo identify several properties of the technology user's formal organization which facilitate technology transfer (7; 39). They include top management support for technology transfer projects, urgency of technical problem resolution, and the organization's decision making style.

The organization's decision making style should be conducive to an innovative atmosphere within the organization. The technology user's organization can also facilitate technology transfer by assigning project managers to transfer projects. The absence of these properties would cause barriers to the transfer process.

Evidence of facilitators and barriers can be used to determine an organization's capacity to use technology transferred from a federal laboratory. Private sector organization's can be surveyed and screened for the properties mentioned in the previous paragraph (27; 39). In particular, private sector organization should possess characteristics of quick product development often associated with small businesses (27; 35). Common barriers that prevent a private sector user from successfully implementing a transferred technology are the lack of technical and management expertise, financial resources, and R&D capability (27; 39).

The technology user's willingness to be helped is another category of factors that affect the technology transfer process. Incubator programs are one indicator of the private sector's willingness to be helped. Private sector incubator programs are established to exploit new technology which impacts existing markets or creates new markets (14; 39). The amount the private sector uses the federal laboratories as a technology source also indicates

willingness to be helped. A factor which adversely affects the private sector's willingness is their perception of the federal bureaucracy's excessive "red tape" procedures (16; 31). Also the lack of timely response by federal laboratories to private sector request for assistance have a negative impact on technology transfer. Lee M. Rivers, formerly a member of the White House Office of Science and Technology Policy and the current FLC President, makes the following statement about this negative impact.

> If a businessman has to take four months to figure out what he needs to do and then has to go through six layers of bureaucracy in Washington, that's going to be tough [on the businessman][16:45].

This factor as well as others impact the private sector user's willingness to be helped by technology transferred from the federal laboratories.

Receiver's View of Technology Credibility and Reward. The technology user's view of federal technology's credibility is a technology transfer determinant. The more mature a technology is the more credibility it has to potential users (7; 14; 27; 39). The GAO study mentioned earlier interviewed federal laboratory technology transfer officials. They felt the laboratories dealt mostly with basic research which is more immature than applied research. They identified this as a barrier to domestic technology transfer (14:9). However, some industries have the same technology needs as the federal laboratories

resulting in "natural" matches for technology transfer. Also, the federal laboratories have greater technical expertise than most small businesses (7; 27). Therefore, small businesses look to the federal laboratories for technical assistance.

The technology receiver must also perceive reward potential for adopting a federal technology. Facilitating attributes in this category provide for commercial protection. Patents, exclusive license agreements, and tariffs for imports all provide commercial protection and facilitate the technology receiver's reward perception (21; 39). Olsen's survey of 160 federal laboratory managers and scientists/engineers found laboratory awareness of patent and licensing procedures to be a barrier (31:73).

Joint ventures with a federal laboratory and shared project funding reduce the private sector's investment risk in developing new technologies or technology applications (7; 31; 39). Unfortunately, concern for unfair public and private sector competition is a significant drawback to cooperative arrangements (14; 16; 27). The GAO report states that in spite of existing legislation "it remains unclear what is permissible in using federal funds to take a technology from the laboratory to the commerical arena" (14:9).

Selection of R&D Projects. The projects selected for transfer or further development affect domestic technology transfer. A technique used by NASA in selecting transfer projects is an industry team concept. Industry teams are experienced industry specialists and opinion leaders who identify "customer needs, products or processes which are potential applications for an innovative technology" (39:54). Assessement studies of technical feasibility and potential markets for technolgy application also facilitate the selection of R&D projects (27; 35; 39). Both industry teams and assessment studies attempt to provide private sector input to federal laboratory project selection. Private sector participation in federal laboratory R&D agenda setting has a positive affect on transferring technology to the private sector (16; 35). A technology transfer barrier in the selection of R&D projects is the lack of federal laboratory awareness of private sector technology needs and problems (7; 14; 16; 39).

Informal Linkers. Informal linkers are personnel who link private sector users with the federal laboratories. These personnel can be in the user's organization, the supplier's organization, or somewhere in between both organizations (33:24). Technology gatekeepers, brokers, and program managers are effective linkers in transferring technology (7; 21; 27; 31; 39).

Personnel who are members of professional and trade associations also have the opportunity to become linkers (14; 27; 39). The personnel who serve in a federal laboratory's ORTA have a central role in linking the laboratory with the private sector (14; 27). Unfortunately, there is a lack of trained personnel to serve as technology transfer specialists in a federal laboratory's ORTA. (14:10). As a result, the available technology transfer specialists are a "harried lot with responsibility for hundreds of different projects" (16:48).

Supplier's Formal Organization. While researching the literature, it became apparent that a category needed to be added to those proposed by Jolly and Creighton. The new category is technology supplier's formal organization and first became apparent after reviewing Olsen's thesis work (Olsen:). Dawson, Gutrel, Meima, and Tornatsky's work also provide information to justify the addition of this category (7; 16; 27; 35). Formal technology supplier organization is defined by the researcher as organizational structure and tendencies towards technology transfer.

Conflicts with federal laboratory mission purpose and public/private sector competition are two of the common barriers to domestic technology transfer. A basic problem in working with private industry is that it is counter to

the federal laboratory mission of serving the general public (16:45). Additionally, transferring technology to specific companies raises a question of fairness in private sector competition (27:8).

> A conflict seems to exist between the industrial client's need for assistance in adapting technical information and hardware and the federal government's historical reluctance to get caught openly supporting private industries' R & D work [27:29].

These conflicts result in the federal laboratory's uncertainty in involving themselves in domestic technology transfer projects (27:8). Other barriers to an organization's ability to transfer technology are a lack of manpower and priority assigned to technology transfer projects (7; 16; 31). The FLC conducted a study, "Interagency Study of Federal Laboratory Technology Transfer Organization and Operation," using a survey of federal agency ORTAs (31:20). Some of the study's major findings reported technology transfer barriers as:

1) lack of funding,
2) lack of management suport/interest or formal policy,
3) lack of sufficient personnel,
4) lack of time,
5) classified or restricted information, and
6) lack of contacts with technology users (31:21)

Dawson and Tornatsky's research differed with Olsen's because both reported that top management support facilitated the domestic technology transfer process (7;

35). A final factor associated with the supplier's formal organization is the private sector's fear of working with a large bureaucracy (7; 31).

Summary of Technology Transfer Factors and Attributes. The factors and attributes affecting the technology transfer process are presented in Tables 4 through 13 to help the reader visualize the material discussed. A discussion follows Table 13 which summarizes the researcher's observations of the literature presented.

Table 4. Documentation Properties

FACILITATORS	BARRIERS
Public sector awareness (14; 39)	Clarity (39)
Handbooks, manuals (21)	Timeliness (27; 39)
Technical summaries, briefs (5; 21)	
Videotapes (21)	
Effective communicative skills (7)	

Table 5. Distribution Properties

FACILITATORS	BARRIERS
Networks (14; 16; 21; 27; 31; 39)	Timeliness (27; 39)
- workshops	Federal laboratory
- mailing lists	locations (27; 35)
- trade associations	Public sector
- conferences	awareness (14)
- professional societies	Lack of resources (39)
Information centers (7; 14; 27; 39)	Chaotic storage of
- NTIS	documents (39)
- DTIC	Security of classified
- Engineering research	technology (16; 31; 39)
Personal Contact (14; 21; 27; 31; 35; 39)	
- Personnel transfer	
- Onsite visits	
- Laboratory visits	
- Consulting	
Demonstration projects (16; 21; 35; 39)	
Cooperative arrangements (14; 31)	
Federal transfer programs (7)	
Diffusion through industry (21; 39)	

Table 6. Formal User Organization Properties

FACILITATORS	BARRIERS
Top management support (7; 39) Decision making policies (7; 39) Innovative atmosphere (7; 39) Technology transfer project management (39) Marketing ability (7; 39) Urgency of problem solution (7)	

Table 7. Properties for Selection of Projects

FACILITATORS	BARRIERS
Assesment studies (27; 35; 39) - technical feasibility - potential market Industry teams (14; 21; 39) Private sector participation in R&D agenda setting (16; 35)	Federal laboratory awareness of private needs/problems (7; 14; 16; 39)

Table 8. User Capacity Properties

FACILITATORS	BARRIERS
Screening criteria (39) Survey (27) Small business responsiveness (27; 35)	Lack of expertise (27; 39) - technical - management Lack of resources (27; 39) - financial - R&D

Table 9. Informal Linker Properties

FACILITATORS	BARRIERS
Gatekeepers (7; 39) Brokers (7; 21; 27; 31) ORTA (14; 27) Professional and trade associations (14; 27; 39) Program managers (39)	Private sector access to federal laboratories (27) Lack of technology transfer specialists (14)

Table 10. Properties Affecting Receiver's View of Technology Credibility

FACILITATORS	BARRIERS
Mature technology (7; 27;39) Similiar tecnical needs (7;27) Federal laboratory expertise (7;27)	Immature technology (14; 27; 39) User awareness of federal technology (7;39) Diverse technology needs (14)

Table 11. Properties Affecting Reciever Reward Perception

FACILITATORS	BARRIERS
Commercial protection (21; 39) - tariffs - patents - exclusive licenses Joint ventures and joint project funding (7; 31; 39) Tax Incentives (35; 39) Gauranteed loans (39)	Investment risk (7; 39) Unfair public/private competition (14; 16; 27) Laboratory awareness of patent procedures (31)

Table 12. Properties Affecting User Willingness to be Helped

FACILITATORS	BARRIERS
Incubator programs (14; 39) Private sector use of federal laboratories (27)	Federal "red tape" (16;31) Lack of timely response to inquiries (16)

Table 13. Supplier's Formal Organization Properties

FACILITATORS	BARRIERS
Top management support (7;35)	Funding for R&D (31) Technology transfer awareness (31) Low technology transfer priority (7; 16) Lack of manpower (16;31) transfer experience (16) Private sector fear of federal bureaucracy (16; 31) Conflict in mission purpose (7; 16; 35)

The researcher observed that several properties were repeated in different categories. One repeating property is the awareness federal laboratories and the private sector have of each other's problems, needs, and technology transfer procedures. This property affects the federal laboratory's R&D project selection and the federal laboratory and private sector's willingness to work with

each other. Also, federal laboratory and private sector awareness affects the documentation and distribution of technology. Another property found in different categories is the availability and allocation of resources by the federal laboratories and private sector for R&D project funding and technology transfer efforts. This property impacts the private sector's capacity to utilize technology, the distribution of technology, and the federal laboratory's formal organization.

Two other properties are found in more than one category. The timely documentation, distribution, and supplier response to inquiries affect technology transfer as well as the technology user's willingness to be helped. A final property found in several categories is the private sector's access/use of the federal laboratory system. This property impacts the private sector's willingness to be helped, the linkers between the federal laboratory and the private sector, and technology distribution.

Not only did properties repeat themselves among categories but some categories appeared to recieve more emphasis in the literature. Technology distribution, the physical means of transferring technology, was most often mentioned in the literature. Facilitating techniques and methods for technology distribution are the networks

available to R&D personnel, central information centers, and personal contacts. Other facilitators to technology distribution are demonstration projects, cooperative agreements, and technology diffusion through private industry.

Informal linkers also were mentioned frequently in the literature. The roles of gatekeepers, technology brokers, federal laborator ORTAs, and professional and trade associations facilitates technology transfer. The absence of linkers presents a barrier. Additionally, the literature reviewed often mentioned the private sector's input to federal laboratory R&D project selection. Facilitators in this category are assessment studies, industry teams, and private sector participation in R&D agenda setting.

Chapter Summary

The literature review was organized into two sections. The first section presented four models which generally explain and describe the theoretical foundations for the technology transfer process. Those models were a predictive model, an innovation model, a marketing model, and a model for government agencies and laboratories. The second section enhanced the theoretical foundations by identifying the factors and attributes which are facilitators and barriers to the domestic technology

transfer process. These two sections establish a frame of reference for understanding and analyzing AFWAL's domestic technology transfer process.

III. Methodology

This chapter's purpose is to describe the research method and design. The researcher chose a research design for qualitative data because "qualitative data are more likely to lead to serendiptious findings and to new theoretical integrations; they help the researcher go beyond initial preconceptions and frameworks" (28:15). In Qualitative Analysis, Miles and Huberman propose that qualitative data are a "source of well grounded, rich descriptions and explanation of processes occurring in local contexts" (28:15). However, the researcher must handle qualitative data carefully. He must analyze qualitative data so that his findings are considered reasonable.

> The most serious and central difficulty in the use of qualitative data is that methods of analysis are not well formulated. For quantitative data, there are clear conventions the researcher can use. But the analyst faced with a bank of qualitative data has very few guidelines for protection against self-delusion, let alone the presentation of unreliable or invalid conclusions to scientific or policy-making audiences. How can we be sure that an 'earthy', 'undeniable', 'serendipitious', finding is not, in fact, wrong [28:16]?

This research effort uses Glaser and Strauss's grounded theory methodology as a guide for a systematic inquiry and analysis of qualitative information that could enhance AFWAL's domestic technology transfer process. The research method is designed to answer the second and third research question. The design for each research question will employ

the techniques and methods proposed by Glaser and Strauss. The first research question is covered in the literature review. The three research questions guiding the study are as follows:

1) What are potential facilitators and barriers to technology transfer?

2) What facilitators and barriers to domestic technology transfer exist at AFWAL?

3) What techniques or methods can AFWAL managers and scientists/engineers use to enhance the domestic technology transfer process?

The following discussion first describes Glaser and Strauss's grounded theory methodology. Next, theoretical sampling, a grounded theory technique for developing theory with conceptual categories and their properties, is discussed. This approach was used in the data collection effort. After discussing theoretical sampling, a research design for each of the research questions is presented.

Grounded Theory Methodology

Dr. Barney B. Glaser and Dr. Anselm L. Strauss published The Discovery of Grounded Theory in 1967 which presented strategies for qualitative research. The Discovery of Grounded Theory was written to protest a "methodological climate in which qualitative research was viewed as only a helpful preliminary to the 'real' methodologies of quantitative research" (5:109). Glaser and Strauss believed "how" theory is discovered from data was equally important as

quantitative verification of theory (13:1). They make the following comment.

> In this book we address ourselves to the equally important enterprise of how the discovery of theory from data--systematically obtained and analyzed in social research--can be furthered [13:1].

Glaser and Strauss define grounded theory as the "discovery of theory from data" and emphasize "a general method of comparative analysis" as a major strategy in using the grounded theory methodology (13:1).

A general method of comparative analysis serves several purposes. First, comparative analysis can give the study validity by the replications of fact achieved in comparing collected evidence with existing evidence (13:23). According to Glaser and Strauss, "facts are replicated with comparative evidence, either internally (within a study), externally (outside a study), or both" (13:23). It is this researcher's understanding that the degree of internal validity depends on the consistency of the results obtained from collected evidence. Also, the researcher understands that external validity is dependent on the collected evidence's consistency with existing theory. However, recognizing emerging concepts from the data rather than validity is the primary purpose of comparative analysis.

> Although this use of comparative analysis is not, of itself our goal, it is definitely subsumed under our goal. Naturally we wish to be as sure of our evidence as possible, and will therefore check on it as often as we can. However, even if some of our evidence is not entirely accurate this will not be too troublesome; for in generating theory it is not the fact upon which we

> stand, but the "conceptual category" (or a "conceptual property" of the category) that was generated from it [13:23].

In addition to the primary purpose of generating concepts, comparative anaylsis is used to generalize evidence to facts. Empirical generalizations can "not only help delimit a grounded theory's boundaries of applicability; more important, they help us broaden the theory so that it is more generally applicable" (13:24).

Comparative analysis is also used to "specify a unit of analysis for a one-case study" (13:25). This comparison must be done "early in the presentation of a study for the purpose of getting the ensuing story straight" (13:26). Getting the ensuing story straight verifies the relevance of conceptual categories (13:26).

> When the analyst turns to theoretical concerns, evidence is invariably used as a test of his hypotheses--and thereby of the relevance of his categories; comparative data give the best test. Both implicitly and explicitly the analyst checks out his theory as the data pour in [13:26].

Neither verification nor accuracy is to overshadow the importance of using comparative analysis to generate theory. Glaser and Strauss make this point very clear.

> Of course, verifying as much as possible with as accurate evidence as possible is requisite while one discovers and generates his theory--but not to the point where verification becomes so paramount as to curb generation. Thus, generation of theory through comparative analysis both subsumes and assumes verifications and accurate descriptions, but only to the extent that the latter are in the service of generation [13:28].

Thus, the primary purpose in using comparative analysis in the grounded theory methodology is to generate theory through emerging concepts from the collected evidence. As concepts which expand or initiate theory emerge through conceptual categories and their properties, the accuracy of the evidence can be confirmed as well as verified.

Glaser and Strauss feel comparative analysis generates two kinds of theory: substantive and formal (13:32). Substantive theory means theory "developed for a substantive, or empirical, area of social inquiry, such as patient care, race relations, professional education, delinquency, or research organizations (13:32). Formal theory deals with the conceptual area of social inquiry like behavior, formal organization, reward systems, and authority and power (13:32). The distinction between substantive and formal theory is one of degree with substantive theory falling within formal theory (13:33). Glaser and Strauss caution the analyst to "focus clearly on one level or the other, or a specific combination, because the strategies vary for arriving at each one" (13:33).

For this research study, a substantive theory for the facilitators and barriers to AFWAL's domestic technology transfer process will be compared to a more substantive theory of technology transfer facilitators and barriers found in the literature. Comparing the factors affecting AFWAL's domestic technology transfer process to a more formal theory could produce results the researcher can use in determining

ways AFWAL could enhance their domestic technology transfer process. Glaser and Strauss suggest the feasibility of using this approach.

> A substantive theory generated from the data must first be formulated, in order to see which of diverse formal theories are, perhaps, applicable for furthering additional substantive formulations [13:34].

Dr. Glaser reinforces this type of comparison in his book, Theoretical Sensitivity, which suggests advances in grounded theory methodology.

> A prominent class of outside comparisons is the literature. It depends on the literature: some comparisons are theoretical concept to concept and others are concept to data. This, of course, integrates both the substantive ethnographic data and theoretical literature to the research study by locating both. It allows for new emergent categories. It extends the theory referred to [12:51].

Theoretical Sampling

Theoretical sampling is a grounded theory technique used to develop theory. For this study, theoretical sampling is used to develop the substantive theory which will be compared to the literature.

> Theoretical sampling is the process of data collection for generating theory whereby the analyst jointly collects, codes, and analyzes his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges [13:45].

Theoretical sampling begins with a partial framework of "local" concepts which the researcher can use to begin his study (13:45). Next, the researcher must become theoretically sensitive so that he is able to

"conceptualize and formulate a theory as it emerges from the data" (12:44).

An initial decision for collecting data is made according to the researcher's perspective of the problem area (12:44). As the researcher collects the data he initially codes it according to conceptual categories and their properties (12:55).

> Coding, the initial phase of the analytic method, is simply the process of categorizing and sorting data. Codes then serve as shorthand devices to label, separate, compile, and organize data [5:111].

For this study, possible initial codes are facilitators to domestic technology transfer and/or barriers. The actual initial codes are developed throughout the data collection effort. From this point on, further data collection and coding is guided by emerging theory (13:47).

An additional activity prior to continuing with data collection is memo writing. "Memos are written elaborations of ideas about the data and the coded categories" (5:120). The researcher establishes the categories by systematically writing memos while coding the data (5:120).

> Memo writing takes place throughout the research process starting with the first interviews or observations. These early memos shape aspects of subsequent data collection; they point to areas the research could explore further. They also encourage the researcher both to play with ideas and to make early assessments about which ideas to develop [5:121].

Following initial coding and memo writing the researcher begins focused coding. Focused coding takes "a limited set of codes that were developed in the initial phase and applies

them to large amounts of data" (5:116). Focused coding is important because it begins to organize larger amounts of data into categories for analysis (5:116). Based on the categories found in the literature, focused coding might develop a category such as activities that facilitate or hinder the distribution of technology. Properties found in this category would include personal networks, formal networks, and security of classifed information. Only as the data collection progresses will the actual category code(s) emerge.

Along with focused coding the researcher must also begin sorting memos. Sorting memos helps to define the conceptual categories for the data.

> Sorting memos simply means putting those that elucidate the same category together in order to clarify its dimensions and to distinguish it from other categories. By going through accumulated memos and sorting them, researchers gain insight into what the core variables, key phases in a process, or major issues are in the research [5:122].

Focused coding and memo sorting eventually leads to an intergration of data. "By integrating the memos the researcher reveals the relationships between categories" (5:123). Initial and focused coding and memo writing, sorting and integrating allows the researcher to discover conceptual categories and properties and their relationships. Defining conceptual categories, identifying their properties, and recognizing relationships permits the researcher to

obtain his main goal of systematic and purposeful theory generation from the collected data (13:28).

Theoretical sampling continues according to the researcher's sensitivity to the theory emerging from the collected data's coding and memos. Theoretical sampling also continues until the data fills, saturates, and exhausts the conceptual categories within the emerging substantive theory (5:125). As suggested in The Discovery of Grounded Theory, substantive theory helps to "generate new grounded formal theories and to reformulate previously established ones" (13:34). In this particular technology transfer study, the researcher attempts to enhance AFWAL's domestic technology transfer process by exploring conceptual categories used to generate theory or reformulate existing theories.

Research Design

The research method is designed to answer each of the research questions. The design for each research question employs the techniques and methods proposed by Glaser and Strauss.

Potential Facilitators and Barriers. The literature review provides the substantive categories which contain potential facilitators and barriers to technology transfer. Jolly and Creighton's formal and informal predictive factors serve as the initial conceptual categories. Potential factors or attributes found in each literature source were evaluated and placed into a cumulative table of conceptual

categories and properties derived from existing formal theory. Chapter II, Literature Review, shows the tables listing the sustantive conceptual categories and their properties found by analyzing each source found in a literature search. The technology transfer theory reflected in Tables 3 thru 13 will be compared to the theory developed with theoretical sampling of AFWAL managers and scientists/engineers.

AFWAL Facilitators and Barriers. Theoretical sampling of AFWAL's managers and scientists/engineers was used to develop the substantive categories which contain facilitators and barriers to AFWAL's domestic technology transfer process. Data were collected using a semi-structured interview format. The researcher patterned the semi-structured interview questions according to the General Orientation Interview found in Diagnosing Organizations by Michael I. Harrison (17:133-138). A list of the semi-structured interview questions and format is in Appendix A. The researcher selected the interview population based on their involvement in past technology transfer projects. ORTA records and referrals obtained during interviews are used to determine those individuals. A total of 18 AFWAL managers and scientists/engineers participated in the interviews. Prior to the interview, each interview candidate was sent an introductory letter explaining the purpose of the interview and their involvement in the study. To facilitate the

researcher's recall of each interview, notes were taken during the interview.

As soon as possible after the interview, the researcher used the interview notes to initially code and memo the data collected in the interview. The purpose of initial coding is to help researchers "look for what they can define and discover in the data" (5:113). Next, the researcher looks for "leads, ideas, and issues in the data themselves" (5:113). After initially coding the data, an initial memo was written. An initial memo should expand codes into broader topics or categories which define the data (5:121). Additionally, the initial memo is used to explore ideas about the research (5:121). Appendix B contains the initial memos written following the interviews. Between interviews and after all interviews were completed, the initial data codes were focused and initial memos sorted and integrated.

To begin the theoretical sampling process, the researcher looked for concepts in the data which facilitated or hindered the domestic technology transfer process. Using an initial framework of these two properties, categories for them began to emerge. Chapter IV, Findings , presents the results from theoretical theoretical sampling of AFWAL managers and scientists/engineers.

Enhancing AFWAL's Technology Transfer. A comparative analysis between the substantive categories found in the literature and developed from the interviews is used to

identify which transfer concepts AFWAL might use to enhance their domestic technology transfer. If the comparison saturates a particular category, AFWAL might consider capitalizing their domestic technology transfer efforts in that area. On the other hand, a new conceptual category or property might emerge which indicates a potential area for improving AFWAL's domestic technology transfer process.

Summary

"Theory is a set of systematically interrelated concepts, definitions, and propositions that are advanced to explain and predict phenomena(facts)" (10:30). This chapter presented a method found in The Discovery of Grounded Theory for discovering theory through comparative analysis of concepts. Next, a grounded theory technique, theoretical sampling, was discussed. Finally, the grounded theory methodology is used to develop a research design for the study's research questions.

IV. FINDINGS

This chapter provides a discussion of the research findings and explains how Glasser and Strauss's grounded theory methodology is used to arrive at them. The first section of this chapter presents an example of initial coding and memo writing done during the research. The second section shows how focused coding is used to develop categories. The second section also shows the results of sorting the memos and putting them in the conceptual categories developed with focused coding. A discussion follows that integrates the memos written during theoretical sampling of AFWAL managers and scientists/engineers. The last section in this chapter is a comparison of the data gathered from theoretical sampling with technology transfer factors and attributes described in Chapter II, Literature Review.

Initial Coding and Memo Writing

Following each interview, the data collected was coded for conceptual categories and a memo written to describe emerging conceptual categories and properties. Coding, the inital phase of analysis, began with categorizing the factors and attributes mentioned in the interviews as facilitating or impeding the domestic transfer process. Table 14 lists these two initial

categories and the factors and attributes associated with each one following one of the early interviews.

Table 14. Initial Category Codes and Properties

FACILITATORS	BARRIERS
Briefings to industry	Awarenes of private sector needs
Technical reports published through DTIC	No incentive for domestic technology transfer efforts
Willingness to further the use of technology	Restrictions imposed for security concerns
	Lack of manpower due to civilian hiring freeze
	Conflict with mission essential projects

The following excerpt is the initial memo written after the interview. In this memo, the researcher felt a broader category was emerging in which organizational concerns and reactions to domestic technology efforts could affect the transfer process.

> The laboratory is willing to participate in domestic technology transfer efforts but what does the government, specifically AFWAL, receive from technology transfer efforts? What are the private questions seem to indicate organizational concern and confusion about domestic technology transfer.

Questions about this emerging category as well as the semi- structured interview questions were used in collecting data in subsequent interviews. By comparing

interview data with conceptual categories and properties developed from previous interview data, the researcher continually analyzed the data while collecting more data.

Focused Coding and Memo Sorting and Integration

In Chapter III, focused coding is described as taking a limited set of codes developed in the initial phase and applying them to large amounts of data. In the above example, a broader category than just facilitators and barriers began to emerge. Organizational concern and confusion about the impact domestic technology transfer has on AFWAL is apparent. Subsequent interviews reinforced this category. Below are portions of interview memos that justify a broader category which includes aspects of organizational behavior.

> What is the policy from the top down for implementing domestic technology transfer? It conflicts with primary mission tasks.
>
> What does the government, specifically AFWAL1, receive from technology transfer efforts?
>
> Policy issues are the crux of the problem. Policy needs to cover individual as well as organizational activities.
>
> The laboratory must use its resources to satisfy mission needs.
>
> Organizational concerns are conflicts with mission priority and support from top management.
>
> Policy must provide guidelines for conflicts in mission priority and unfair competition.
>
> Technology transfer efforts must insure fairness to all businesses in the private sector. This results in conflicts in mission priority and use of resources.

This interview data makes the point that organizational behavior has significant impact on the domestic technology transfer process. Organizational behavior includes organizational activities, reaction, concerns for domestic technology transfer efforts.

Several other categories emerged from focused coding of the the interview data. They include individual behavior, technology characteristics, documentation, and distribution. Along with focused coding, which determines the categories, the memos are sorted. Sorting memos simply means putting together the ones that clarify the same category. Tables 15- 19 show how the researcher sorted the interview memos among the different categories. The tables display all the categories, descriptions, and facilitator/barrier properties resulting from the interviews. The value in parenthesis indicates the number of interview respondents who emphasized the property. An integration of the memos from the interview data follows Table 19.

Several properties mentioned during the interviews are found in more than one conceptual category. AFWAL and private sector awareness and assessment of each others technology, capability, and transfer procedures are domestic technology transfer properties found in organizational behavior, technology characteristics, and distribution. The lack of technology transfer guidance

Table 15. Distribution: The physical means for transferring technology

FACILITATORS	BARRIERS
Technical report and information databases (12)	Lack of space for small business at government sponsored briefings
Government and private sector sponsored seminars (9)	
Personal contact through face to face meetings (3)	
Mailing lists	
Marketing efforts through advertising or publicity (4)	

Table 16. Technology Characteristics: Properties affecting the development, application, and appeal of technology

FACILITATORS	BARRIERS
Transfer projects benefiting public/private sector's understanding of technology (6)	Advanced technology acceptance within the AFWAL community
Technology maturity (2)	Immature technology/lack of test data support
Practical application of existing technology	Unreasonable private sector expectations (2)
	Private sector awareness/ expertise

Table 17. Individual Behavior: Individual activities, reaction, and concerns for domestic technology transfer efforts

FACILITATORS	BARRIERS
Willingness to participate in transfer projects (5)	Incentives to participate in transfer activities (4)
Membership in technology R&D and/or application network such as professional societies, personnel transfer arrangements, and consulting agreeements (9)	Lack of policy guiding technology transfer activity (3)
Initiative to transfer personal knowledge (2)	Lack of feedback/follow up opportunity following transfer efforts (4)
	Additional workload caused by transfer projects
	Lack of equity in public/ private sector benefits for scientists/engineers

Table 18. Organizational Behavior: Organizational activities, reaction, concerns for domestic technology transfer efforts

FACILITATORS	BARRIERS
Broker agents such as ORTA/ OTTO (4)	Awareness and assesment of private sector needs (7)
Cooperative agreements for R&D and technncial assistance (4)	Restrictions imposed for security concerns (8)
Immediate supervisor support for transfer activities (3)	Lack of manpower and travel funding for transfer projects (14)
Private sector visits to AFWAL (2)	Conflict with mission essential projects (6)
AFWAL sponsored demonstration projects (2)	Guidance for technology transfer activity, proper AFWAL/private sector relationship, and unbias release of information (11)
AFWAL relationship with defense materiel suppliers and vendors (4)	

Ad hoc inquiries	Patent and licensing procedures (2) Lack of formal agreements for cooperative R&D efforts (2) Excessive regulation in R&D contracting and software usage (4) Private sector contribution to the transfer process

Table 19. Documentation: format, specification, and presentation of AFWAL R&D technology or information

FACILITATORS	BARRIERS
Technical reports for general publication (11) Technical abstracts describing current research projects and expected results	

presents a barrier to both individual and organizational behavior. Another repeating property is technology networks. Membership or access to a technology network facilitates technology distribution and individual behavior in transfer activities. A final property found in more than one conceptual category is the use of technical reports to facilitate technology documentation and distribution.

Some conceptual categories and their properties appeared to dominate the interview data. One category, organizational behavior is facilitated most by technology brokers such as ORTA and OTTO agents, cooperative agreements for R&D, and AFWAL's relationship with defense materiel suppliers and vendors. The common organizational barriers to technology transfer are the lack of manpower and travel funding for transfer activities and the lack of guidance for transfer activities. Security concerns, awareness and assessment of private sector needs, and transfer activity conflicts with mission essential projects are also organizational behavior barriers to technology transfer.

Technical reports available through information databases, seminars, and demonstrations were mentioned the most often as facilitating technology distribution. Additionally, technical reports were the primary means of documenting technology and scientific information. Lastly, membership in technology R&D or application networks such as professional societies, personal contacts, and consulting agreements appear to be the most common facilitators in an individual's behavior in transfer technology.

Comparative Analysis

The last section in this chapter compares the conceptual categories and properties developed from the

literature and interviews. Table 20 summarizes the repeating technology transfer properties and significant categories identified in the literature. Table 21 shows the same information for the interview data. Table 20 and 21 aid the comparison of AFWAL factors and attributes affecting technology transfer to those found in the literature. AFWAL managers and scientists/ engineers perceive several barriers to technology transfer

Table 20. Repeating Theoretical Properties and Significant Categories

Repeating Property	Affected Category
Federal laboratory and private awareness of each other's needs, problems, and transfer procedures	- R&D Project Selection - Willingness to be helped - Technology Documentation - Technology Distribution
Federal laboratory/private sector availability and allocation of resources	- R&D Project Selection - User Capacity - Technology Distribution - Supplier Organizational Behavior
Timely documentation, distribution, and federal laboratory response to technology requests	- Technology Documentation - Technology Distribution - Willingness to be helped
Private sector access to the federal laboratory system	- Technology Distribution - Willingness to be helped - Informal linkers
Significant Categories: Technology Distribution, Informal Linkers, R&D Project Selection	

Table 21. Repeating AFWAL Properties and Significant Categories

Repeating Property	Affected Category
AFWAL and private sector awareness and assessment of each other's technology, capability, and transfer procedures	- Technology Distribution - Technology Characteristics - Organizational Behavior
Guidance for technology transfer activities and relationships	- Individual Behavior - Organizational Behavior
Technology networks	- Technology Distribution - Individual Behavior
Technical Reports	- Technology Documentation - Technology Distribution
Significant Categories: Organizational Behavior, Technology Distributon	

that are also mentioned in the literature. One of the common barriers is the lack of manpower and travel funding for technology transfer activities such as attending seminars and visiting private sector industries. Another is public and private sector awareness of each others existing technology, technical needs, and transfer procedures. Both the literature and interview data show private sector input to R&D project selection as a key determinant to awareness. A different barrier is that domestic technology transfer projects are often seen as conflicting with the laboratory's mission essential R&D. Without guidance, this barrier causes AFWAL managers and scientists/engineers difficulty in prioritizing their R&D efforts and decisions. A lack of guidance in this area

and the proper relationship between AFWAL and the private sector is also a barrier.

The lack of guidance for organizational and individual behavior for technology transfer activities is evident from the interview data. Guidance is needed to define the proper relationship between AFWAL and the private sector. The literature recognized unfair public/private competition as a possible consequence of an improper relationship between federal laboratories and the private sector. Also, AFWAL managers and scientists/engineers expressed legitimate concern for the extent of their participation in domestic technology transfer projects. The data collected from interviewing AFWAL personnel indicates the lack of guidance for organizational and individual behavior as a significant barrier to the domestic technology transfer process.

The interview data and literature review also agree on the facilitating techniques and methods for transfering technology. Both sets of data identified federal laboratory and private sector sponsored seminars to be a primary method of facilitating technology transfer. Technology networks formed by membership in professional and trade societies, personnel transfer arrangements, and/or cooperative agreements further the transfer of technology. Personal contact between technology supplier and technology user also facilitates the transfer process.

Linkers who match the technology supplier with the technology user assist personal contacts.

A final significant area of agreement between the literature and interview data is the use of technical reports as a means of transferring technology. Over half of the interview respondents mentioned technical report publication as a primary method of transferring technology. However, none mentioned the lack of timely transfer associated with the publication process. The literature listed timeliness in documentation and distribution of technical reports as a barrier in transferring technology.

As suggested by Glasser and Strauss's grounded theory methodology, the comparison between interview data and the literature allows for either new emerging categories, extending theory, or both. The research indicates important emerging categories that extend technology transfer theory found in the literature. The important emerging categories are organizational behavior and individual behavior of technology suppliers. In the literature, Jolly and Creighton's formal and informal factors did not include the technology supplier's organizational properties. However, the literature did suggest such a category did affect the technology transfer process. Also, the research conducted at AFWAL identified organizational behavior as a significant conceptual

category affecting the domestic technology transfer process. Therefore, the technology supplier's organizational properties or characteristics should be included as a significant factor affecting the transfer of technology.

Another emerging category is individual behavior of those personnel who possess the technology to be transfered. The literature identified informal linkers as individuals who link technology sources with technology users. The literature review placed technology gatekeepers, brokers, ORTA personnel, professional and trade association members, and program managers in this category. However, interviewing AFWAL managers and scientists/engineers suggests there is a distinction within this category. Broker agents such as ORTA and OTTO personnel are identified as an organizational behavior property which facilitates linking the technology user/requester with the individual possessing or having access to the required technology.

The linkers, such as broker agents or program managers, could not be expected to always possess or know where to find the needed technology. However, they do have access to knowledgable individuals who can provide or acquire the technology. Professional and trade association members are more likely to be the knowledgable

individuals who possess or have access to the needed technology.

The research indicates individual behavior of those possessing or having access to the technology impacts the domestic technology transfer process. The research found their willingness and initiative to particapate in domestic technology transfer projects are properties of individual behavior. The lack of incentives, feedback, and follow up opportunity adversely affects the transfer process.

Because the research indicates a distinction within Jolly and Creighton's informal linker category, a new category has emerged. This category accounts for the individual behavior of those who possess or have access to technology. The informal linker categrory still remains an important factor and includes those who link technology sources with technology users.

Summary

This chapter provided a discussion of the research findings and explained how Glasser and Strauss's grounded theory methodology was used to develop the research findings. The first section presented an example of initial coding and memo writing which began to establish organizational behavior as an important factor affecting AFWAL's domestic technology transfer process. The next section show how focused coding developed conceptual

categories. Five categories, organizational behavior, individual behavior, technology distribution, technology documentation, and technology characteristics, were developed. The memos were sorted according to these five categories. The memos were integrated in a discussion and four properties were identified that existed in more than one category. Those properties are AFWAL and private sector awareness and assessment of technology transfer capabilities, the lack of organizational and individual technology transfer guidance for AFWAL, technology transfer networks, and technical reports for distributing technology.

The last section compares data collected through theoretical sampling of AFWAL managers and scientists/engineers to technology transfer factors and attributes described in the literature. Both the interview data and the literature agree on some common facilitators and barriers. Common barriers found in both for AFWAL and the private sector include the lack of manpower and funding for technology transfer efforts and awareness of the other's technology and transfer capabilities. Another barrier found in the literature and AFWAL is the lack of private sector input to R&D project selection. Additionally, the lack of organizational and individual guidance for AFWAL is a common barrier to domestic technology transfer.

Common facilitators are the documentation and distribution of technology using technical reports. However, AFWAL managers and scientists/engineers did not identify the lack of timeliness in responding to technology needs using this transfer method and the literature does. A common facilitator both agree on is the important role linkers have in the technology transfer process.

In addition to identifying areas of agreement, the comparison extends technology transfer theory. The comparison verifies the technology supplier's organization as an important factor in technology transfer as was suggested by the literature. The comparison also suggests an emerging category distinguishes itself within the theoretical informal linker category. The emerging category considers how individual behavior of those who possess or have access to technology impacts the technology transfer process.

V. Recommendations

The research problem for this thesis is to recommend ways AFWAL can enhance the technology transfer process to the private sector. In Chapter IV, Findings, Glasser and Strauss's grounded theory methodology for a "general method of comparative analysis" identified properties that facilitate and present barriers to AFWAL's domestic technology transfer process. A comparison with the literature suggests ways AFWAL can enhance the technology transfer process. The first section in this chapter recommends enhancing AFWAL facilitators and minimizing or eliminating barriers as suggested by the research. This chapter's second section makes recommendations for further research in technology transfer theory.

Recommendations for AFWAL's Domestic Technology Transfer

The research suggests three areas for potential improvement affected by domestic technology transfer facilitator or barrier properties. The three areas are guidance for organizational and individual behavior, timeliness in technology documentation and distribution, and AFWAL and private sector awareness of each other's technology needs and capability.

Technology Transfer Guidance. The first recommendation is for AFWAL to provide more guidance for

organizational and individual behavior. The lack of guidance presents a barrier to AFWAL's domestic technology transfer. Guidance is needed to define the proper relationship between AFWAL and the private sector which prevents unfair public and private competition. Guidance is also needed for individual behavior of AFWAL personnel when participating in domestic technology transfer activities. This guidance should establish the limits for personal participation in domestic technology transfer projects.

Technology Documentation and Distribution Timeliness. The second recommendation is to decrease the time lapse between technology development, documentation, and distribution. Using existing facilitators and eliminating barriers can decrease the time lapse between technology development, documentation, and distribution. Publishing technical reports is identified as a common means for transferring AFWAL technology but the literature identifies the lack of timeliness caused by the publication and distribution process as a barrier. AFWAL can overcome this barrier with existing facilitators such as seminars, professional and trade association membership, and cooperative agreements. However, the lack of manpower and travel funding to support these transfer activities presents a barrier. To overcome this barrier

AFWAL should increase manpower and travel funding for domestic technology transfer activities.

AFWAL and Private Sector Awareness. The research indicates AFWAL and private sector awareness of each other's technology, needs and transfer procedures is a barrier to domestic technology transfer. AFWAL can use several techniques to eliminate this barrier. One is to provide for private sector input in the selection of R&D projects. Another is to invite the private sector into the laboratory to increase their awareness of laboratory technology and capability as well as foster personal contacts which facilitate the transfer process. These activities can be seen as conflicting with AFWAL's primary mission but guidance to resolve this conflict would facilitate domestic technology transfer.

Recommendations for Future Research

Additional reseach is recommended for AFWAL's domestic technology transfer process and technology transfer theory. Further research is necessary to quantify the factors found in this research affecting AFWAL's domestic technology transfer process. Quantifying these factors will lend increased validity to them in addition to establishing their relative importance to the domestic technology transfer process. This information will also allow AFWAL to improve domestic technology transfer.

This research identified organizational and individual behavior as important concepts in technology transfer theory. Future research should consider these concepts as important factors affecting technology transfer.

Appendix A: Semi-Structured Interview Questions

How would you describe your experience with domestic technology transfer? How often? Successful or Unsuccessful?

Which successful or unsuccessful technology transfer projects are you familiar with and who were the key laboratory people involved?

How are decisions made to enter into a domestic technology transfer project?

What problems do you associate with transferring laboratory developed technology to the private sector?

What are the main techniques and means your unit uses to transfer technology to the private sector?

What works best to facilitate the domestic technology transfer process?

Are there any difficulties and barriers to transferring technology to the private sector as you would like to do it?

What do you see as the main challenges in domestic technology transfer that face your unit now and in the next two or three years? Do you have any suggestions for how to handle them?

What do you feel are the main strengths of your unit to successfully support the domestic technology transfer process?

What must change to successfully support the domestic technology transfer process? Why would these changes be most helpful?

What are the rules, procedures, or policies for domestic technology transfer and how do they affect the transfer process?

Appendix B: Initial Memos from Interview Data

The laboratory could do a better job transfering technology to the private sector but right now it is a nuisance to laboratory personnel. It takes away time from doing more important mission related tasks. However, laboratory personnel are willing to talk to anyone who comes to the laboratory for assistance.

What is the policy from the top down for implementing domestic technology transfer? Domestic technology transfer conflicts with the laboratory's primary mission and limited funding.

The laboratory is willing to participate in domestic technology transfer efforts but what does the government, specifically AFWAL, receive from technology transfer efforts? What are the private sector's needs? These questions seem to indicated organizational concern and confusion about domestic technology transfer.

Policy issues are the crux of the domestic technology transfer problems. Thes policy issues revolve around security concerns for military critical technology, release of information, and patents. Policy needs to cover individual as well as organizational activities. Individual and organizational behavior is important to the transfer process.

The laboratory has no functional problems with trying to transfer technology to the private sector. Improving domestic technology transfer is limited by the initiatives of the laboratories. What factors are barriers to initiative?

There is no real initiative now for domestic technology transfer. An example is the recent regulation controlling the transfer of software. When private industry and the government work as a team both benefit. The lack of policy guiding this interaction presents a barrier to domestic technology transfer.

Laboratory personnel are more than willing to share their expertise and technology. However, the security of military critical technology is an area requiring judgement and filtering of private sector requests.

On the average the private sector needs "intermediate technology" which is laboratory developed and proven technology not yet known by the private sector. The tools necessary to accomplish domestic technology transfer are incentives for laboratory personnel, time allotment away from primary duties, and policy guiding transfer activities. Incentives include comparable wages relative to private sector scientists/engineers, travel to technology network activities, and recognition. Policy must provide guidelines for conflicts in mission priority and unfair competition.

The laws and directives mandating domestic technology transfer are a "nice idea" but unworkable. The laboratory resources are barely sufficient to develop the technology needed by the military. First, technology must be developed and demonstrated before the private sector accepts it.

Technology no longer requiring security classification should be categorized as public domain technology and made available. The laboratory does not have the manpower to do this adequately. Domestic technology transfer works best when the private sector "comes into" the laboratory because they are best able to assess available technology. Good technology sells itself.

Getting the technology out of the laboratory is the best way to enhance domestic technology transfer. Travel funding to attend seminars, conferences, symposiums, etc. affects this more than anything else. Travel funding is subject to budget constraints and is one of the first areas to be reduced.

Domestic technology transfer is a two-way street. The laboratory is willing to do all that it can but the private sector has to take the initiative. The laboratory must use its resources to satisfy mission needs. The benefit received from working with the private sector must justify the expense. As a rule of thumb no more than 80 manhours should be committed to a technology transfer project.

Technology transfer is the "right thing to do for the right reason." However, implementing it is dificult because of legal and organizational logjams. Legal concerns are the use of public resources for private sector gain and patent and licensing issues. Organizational concerns are conflict in mission priority

and support from top management. Domestic technology transfer is an inherent good like apple pie and motherhood. What really needs to be done is for the laboratory to market itself and its technology.

It does not make sense to commit time and resources to domestic technology transfer efforts when mission needs go unfilled. Who will decide which is a priority? This respondent feels that his unit is barely capable of doing 50% of the research and development to meet the needs of the military. The private sector does not need the level of technology that the military does.

Domestic technology transfer happens in a natural, unstructure way as a result of a "good idea." Structured technology transfer must insure fairness to all businesses in the private sector. One way is mass advertising and unresticted attendence at conferences or laboratory "open houses." Structured technology transfer results in conflicts in mission priority and use of resources.

A technology network which exists under some formal agreement, such as EMTEC, really makes technology transfer happen. The formal agreement eliminates individual concerns about unfair competition, allowing laboratory personnel to contribute their expertise restricted only by military security considerations. Additionally, technology networks benefit the laboratory because it gets to apply its technology in a different way. Applying technology in different ways expands what is known about that particular technology.

Deciding how much resources to commit to a technology transfer project is difficult. Laboratory personnel are best qualified to make that decision based on mutual benefit received from a technolcgy transfer project, sensitivity of military security, and available resources.

The unique application of laboratory technology does not readily lend itself to private sector needs. When it does, it must be distributed fairly. The only way to do this is to not restrict access to it.

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This thesis investigates the factors affecting technology transfer from the Air Force's Wright Aeronautical Laboratories (AFWAL) to the private sector and recommends ways to enhance AFWAL's technology transfer process. The study has three research objectives: 1) determine potential facilitators and barriers to technology transfer; (2) investigate the facilitators and barriers to domestic technology transfer at AFWAL; and (3) recommend techniques or methods AFWAL managers and scientists/engineers can use to enhance the domestic technology transfer process. Since the data for this study is obtained from only one federal R&D center, findings are limited to this environment. However, the research findings suggest conceptual areas important to follow-on research.

The research uses Glaser and Strauss's grounded theory methodology as a guide for gathering and analyzing data. Data is collected by interviewing 18 AFWAL managers and scientists/engineers. The interview data is analyzed and placed into five conceptual categories. The five conceptual categories are organizational behavior, individual behavior, technology distribution, technology documentation, and technology characteristics. The analysis shows that four factors affecting the technology transfer process exist in more than one category. These factors are AFWAL and private sector awareness and assessment of technology transfer capabilities, the lack of organizational and individual technology transfer guidance at AFWAL, the importance of technology transfer networks, and the use of technical reports for distributing technology.

Comparing the collected data to theoretical factors and attributes affecting technology transfer shows three areas for potential improvement to AFWAL's domestic technology transfer process. The three areas are guidance for organizational and individual behavior, timeliness in technology documentation and distribution, and AFWAL and private sector awareness of each other's technology needs and capability.

The study also recommends future research should recognize organizational and individual behavior as important variables affecting domestic technology transfer.

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